Computer modelling of cerebral aneurysm hemodynamics

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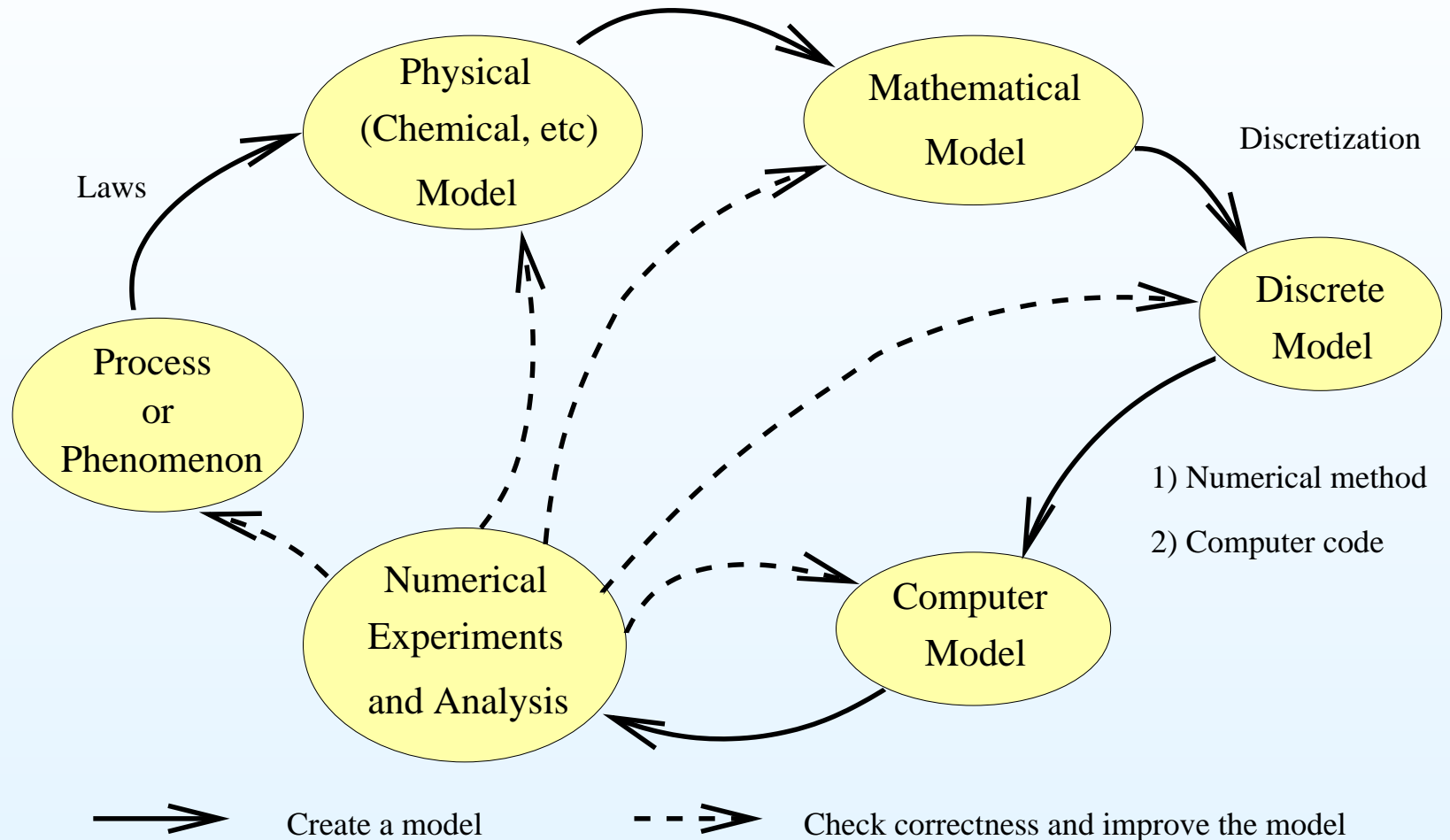Bulgarian Academy of Sciences

Outline

- Computer modelling stages
- Cerebral aneurysm hemodynamics
- Computational domain
- Numerical solution
- Another blood related problem

Computer modelling stages

Cerebral aneurysm hemodynamics

Cerebral aneurysm facts

Brain Aneurysm

Ruptured aneursym

Circle of Willis

Saccular aneursym

Fusiform aneursym

Bottom view of brain and major arteries of the brain

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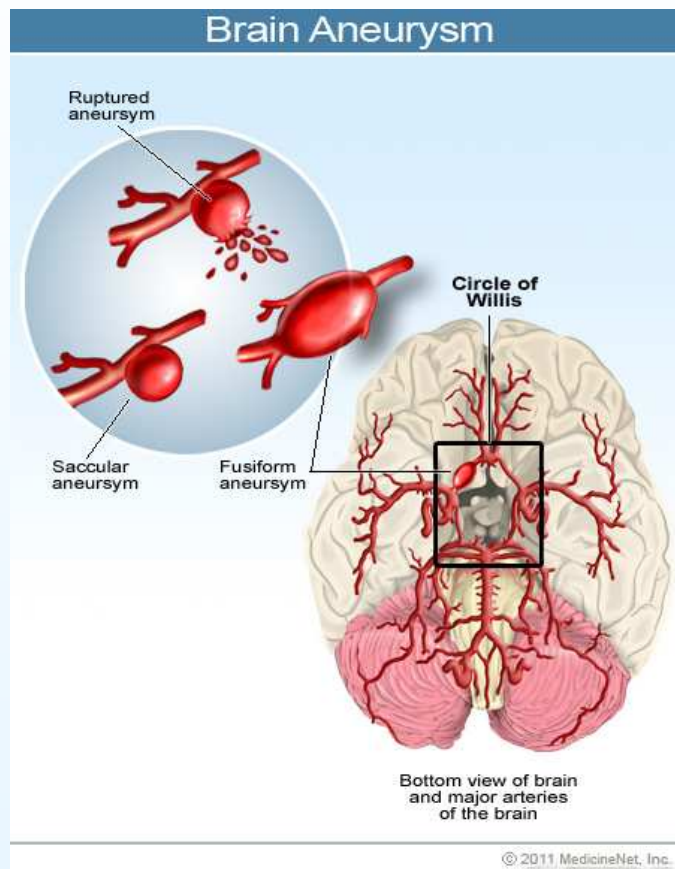
- Four major blood vessels form the Circle of Willis at the base of the brain. Smaller branch arteries supply brain cells with oxygen and nutrients.
- Artery junction points may become weak, causing ballooning of the blood vessel wall that can form a small sac or aneurysm.
- Cerebral aneurysms are common, but most are asymptomatic and are found incidentally at autopsy.
- Aneurysms can leak or rupture causing symptoms from severe headache to stroke-like symptoms, or death.

- Diagnosis of a brain aneurysm may require CT scans, lumbar puncture, or angiography.
- Treatment to repair the aneurysm may involve neurosurgery to put a clip across the weak blood vessel wall or clipping by interventional radiology.

Mathematical model for blood flow

Equations: unsteady Navier-Stokes equations for an incompressible fluid – involved are the velocity, pressure, density, deviatoric stress tensor, viscosity of the blood

Computational domain is blood vessel with aneurysm and appropriate boundary conditions on the inflow, outflow and the vessel walls.

Patient specific data obtained via Digital Subtraction Angiography is used to extract the computational domain
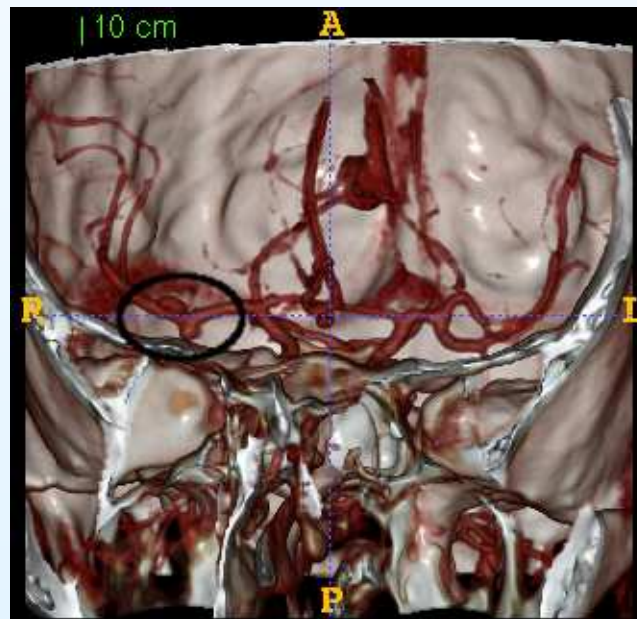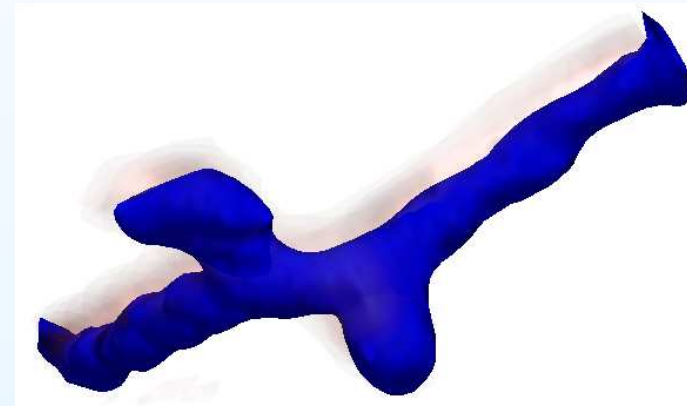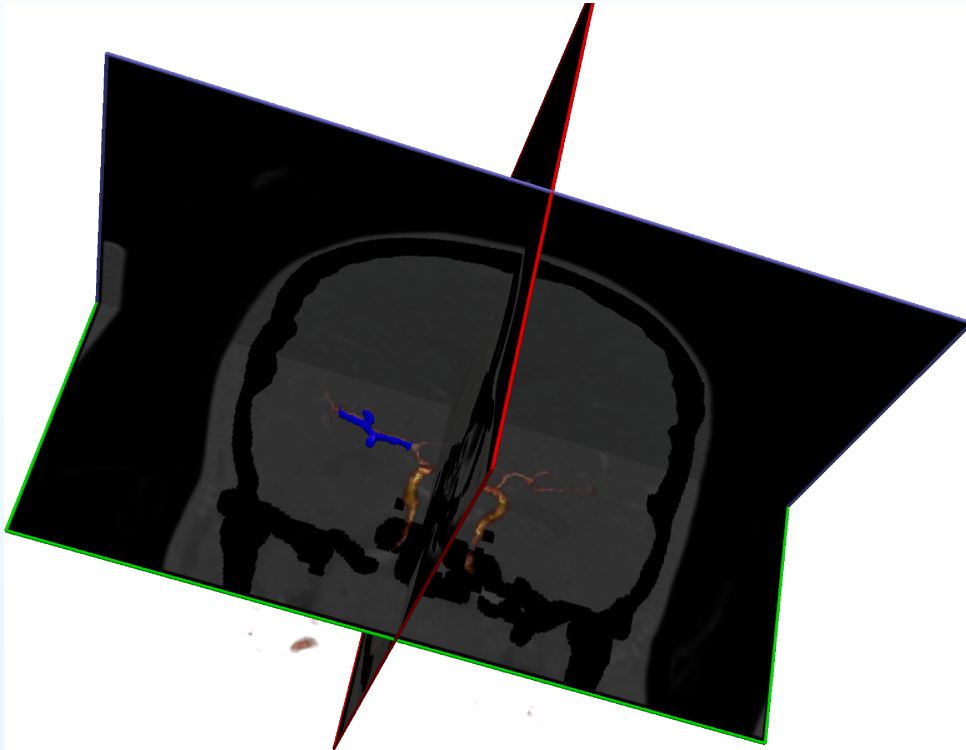

Skull

Blood vessels

Computational domain

GIMIAS – software for processing of medical images

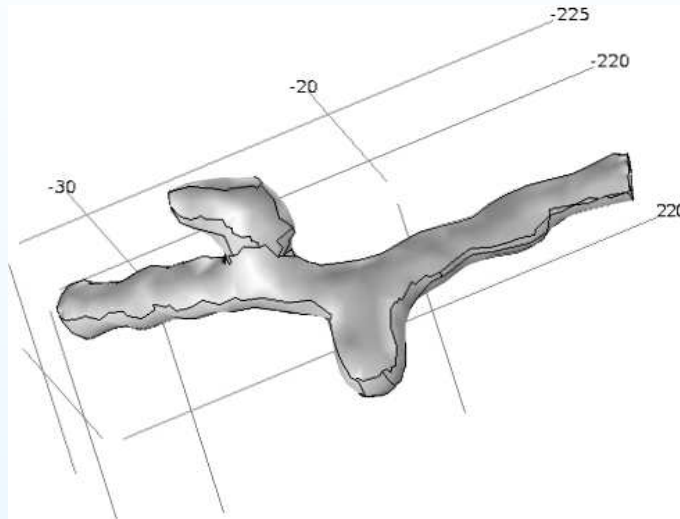Skull with tissues (gray), blood vessels (orange-brown), part of vessel with aneurysm (blue)
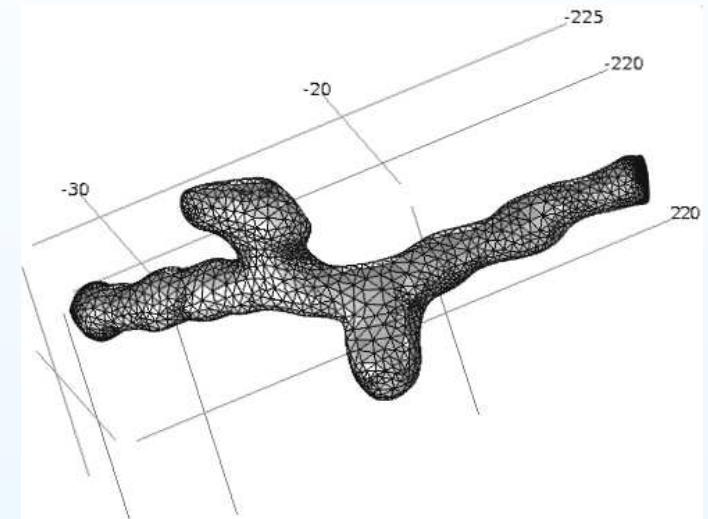
Computational domain – cont.

Computational domain

Tetrahedral mesh

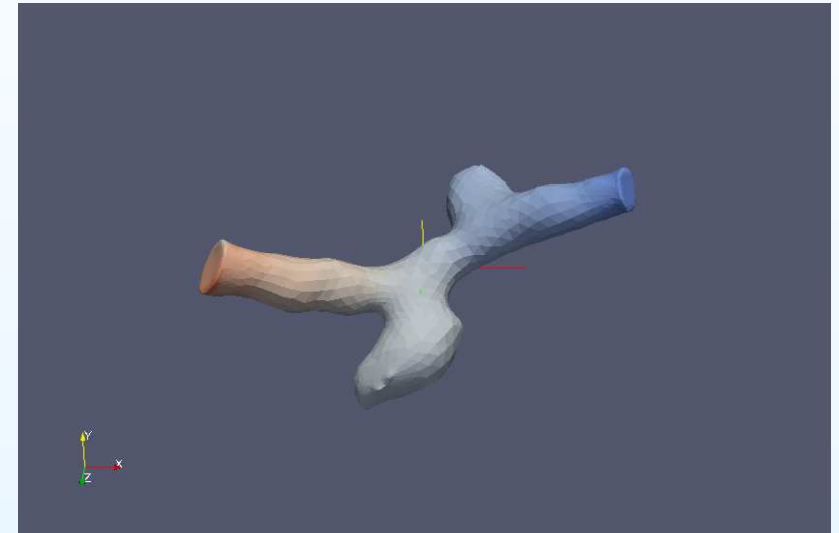NetGen/Tetgen to generate the mesh

Numerical solution

Numerical solution via Finite Element or Finite volume method;
Specialized software: Elmer, Comsol, Code_Saturne
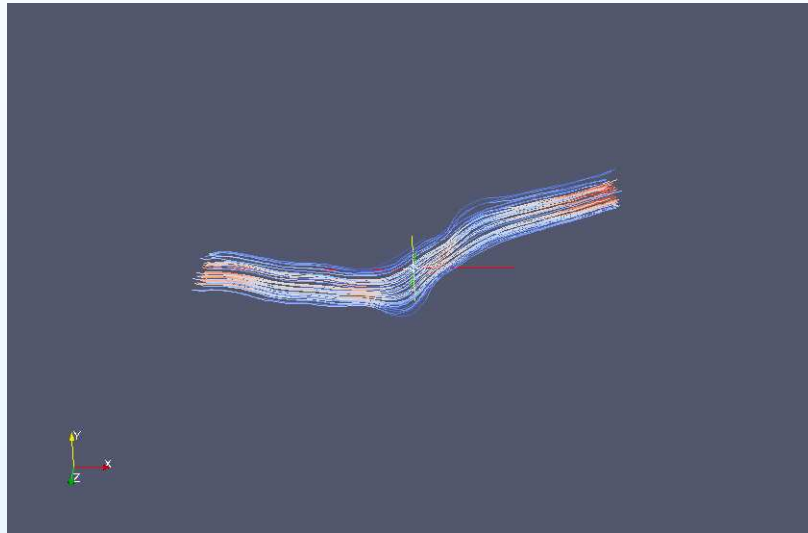
Stream

Pressure

Joint work with Assoc. Prof. Ivan Lirkov

Another blood related problem

Blood cells production and regulation

Haematopoietic pluripotent stem cells (HSCs) in bone marrow give birth to the three blood cell types.

Growth factors or **Colony Stimulating Factors** (CSF) – specific proteins that stimulate the production and maturation of each blood cell type.

Blast cells – blood cells that have not yet matured.

Blood cell type	Function	Growth factors
Erythrocyte	Transport oxygen to tissues	Erythropoietin
Leukocyte	Fight infections	G-CSF, M-CSF, GM-CSF, Interleukins
Thrombocyte	Control bleeding	Thrombopoietin

Various **hematological diseases** (including leukaemia) are characterized by **abnormal production** of particular blood cells (matured or blast).

Main stages in the therapy of blood diseases:

TBI: Total Body Irradiation – kill the "tumour" cells, but also the healthy ones.

BMT: Bone Marrow Transplantation – stem cells of a donor (collected under special conditions) are put in the peripheral blood.
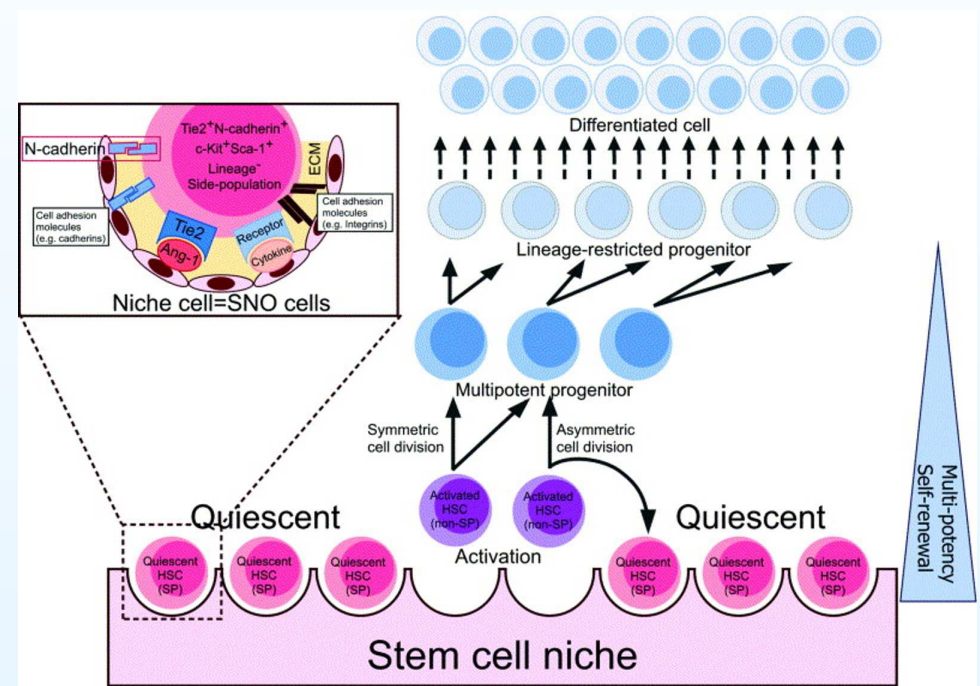
HSCs after BMT ...

1. find their way to the stem cell niche in the bone marrow; and ...

2. self renew and differentiate to regenerate the patient's blood system
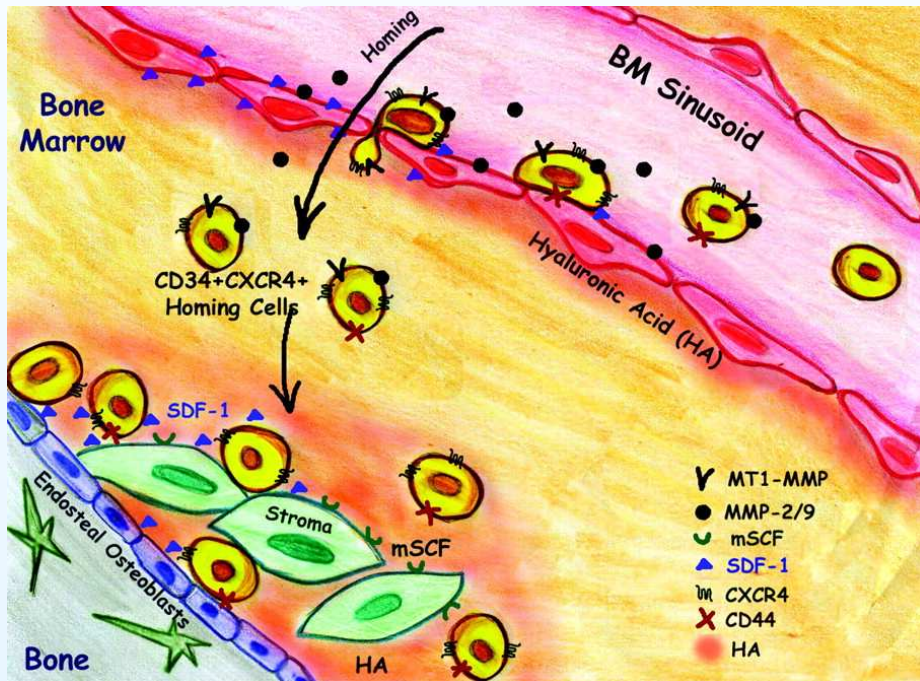
T. Lapidot, A. Dar, O. Kollet, 2005

T. Suda, F. Arai, A. Hirao, 2005

Thank you for your attention!